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ITEM OF INTEREST

Prepared by

Aerospace Information Division

SUBJECT: Explosive Forming

SOURCE: Navagin, Yu. S. Ispol'zovaniye energii podvodnogo vzryva dlya listovoy shtampovki (vytyazhki) (Utilization of the energy of an underwater explosion for deep drawing). Leningrad, Leningradskiy dom nauchno-tekhnicheskoy propagandy, 1961. 29 p.

The source was presented as a paper at a seminar on the cold forming of metals at the Leningrad House of Scientific and Technical Propaganda. The author, who together with V. I. Yeremin suggested explosive forming of sheet metal as early as 1956 (Authors' Certificate No. 122731), describes his studies and experiments. The latter were carried out with the participation of V. I. Buslayev, A. D. Yablochkov, B. Ye. Yakovlev, and others.

The change of shock-wave pressure against the blank p_{sw} as a function of time is approximated by the following exponential function:

$$p_{sw} = \begin{cases} 0 & \text{with } t < \frac{R}{c_0} \\ p_m \cdot \exp \frac{R/c_0 - t}{\theta} & \text{with } t > \frac{R}{c_0}, \end{cases} \qquad (17)$$

where t is the time after detonation of the explosive charge; R, the distance from the charge to the surface of the blank; c_0, the shock-wave velocity assumed to be equal to the velocity of sound in water (c_0 = 1500 m/sec); p_m, the maximum pressure of the shock-wave front; and θ, the exponential constant characterizing the rate of pressure drop behind the wavefront, in seconds.

In addition to p_m and θ, the specific pressure pulse j_0 and the density-of-energy flow q_0 are important parameters of the underwater shock wave. When the shock wave falls on the sheet blank and the die, the pressure acting on them is of an extremely complex character, being determined primarily by the

strength and inertial characteristics of the blank and by the relation between the size of the blank and the length of the shock wave.

In accordance with the theory of similarity developed by L. I. Sedov, the author lists the following parameters as having an influence on the process of the deep drawing of a circumferentially clamped sheet by an underwater shock wave: 1) p_m, kg/cm²; 2) θ, sec; 3) radius of die impression a_0, cm; 4) sheet blank thickness δ, cm; 5) depth of deep-drawn dome h_m, cm; 6) yield point σ_y, kg/cm²; 7) density of the sheet material ρ, kg·sec²/cm⁴; 8) water density ρ_0, kg·sec²/cm⁴; and 9) sound velocity in water c_0, cm/sec.

To determine the dependence of the ratio of the pressure pulse accepted by the blank (I) to that acting on the blank (I_0) on the above parameters (equation 30), the author analyzed a large number of experimental data obtained in explosive forming as shown in Fig. 1.

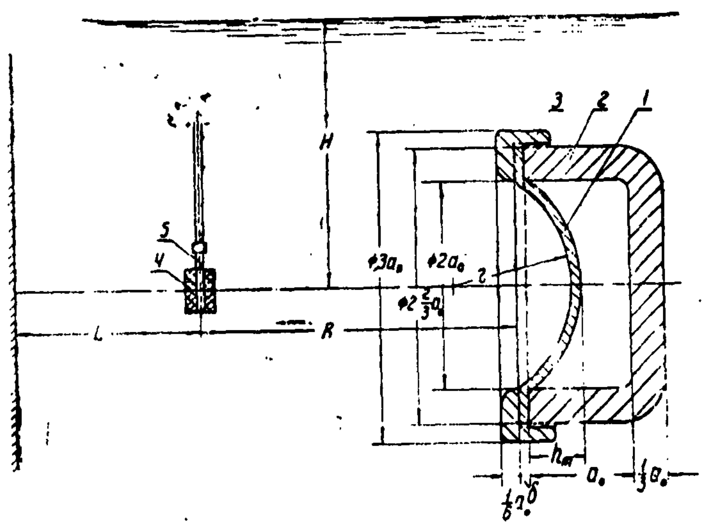

Fig. 1. Arrangement of the equipment for carrying out experiments in explosive forming

1 - blank; 2 - die; 3 - holding ring;
4 - trotyl charge; 5 - electric detonator

(Since the space between the deep-drawn part and the die bottom was sufficiently large, no air evacuation was necessary.) The analysis of experimental data showed that the effect of some parameters in equation (30) can be neglected and the equation

can be simplified as follows:

$$\frac{I}{I_0} = 0.17 \sqrt{\frac{a_0}{c\theta}}. \tag{37}$$

By substituting the values of the parameters in this equation and deriving the equation for the energy Q absorbed by the blank during its deformation, the author obtains the following equation for the weight of the trotyl charge (in grams) required for deep drawing

$$G = 0.0345 \frac{c}{c_0} \frac{\rho}{\rho_0} \frac{\delta}{a_0} \frac{R^2}{S_0}, \tag{43}$$

where Q is expressed in kg-cm; R, in cm; c, the velocity of sound in the blank material, m/sec; and S_0, the blank surface area, in cm^2. To determine static pressure p at which the blank is deformed to the same degree as under the action of the shock wave p_m, the following equation is derived for the coefficient K, which is the ratio of $\frac{h_m \text{ explosion}}{h_m \text{ static}}$ under the condition that $p_m = p$:

$$K \backsimeq 0.48 \frac{c\theta}{a_0} \tag{46}$$

For the range of $\frac{a_0}{c\theta} = 0.7\text{-}10$, the value of K varies from 0.57 to 0.15. The experiments in the explosive forming of copper, aluminum, duralumin, and carbon steel sheet 0.5-3 mm thick showed that the elongation of an explosively formed material is from 15 to 30% and that the depth of deep drawing is more than 20% greater than that in static deep drawing.

In the second part of the paper, the author discusses a method of recording the time dependence of the depth of an explosively formed dome. The method is based on the changes of the capacitance of a capacitor in which the blank being deformed *2* and a plate *4* fastened to the die serve as capacitor plates (see Fig. 2).

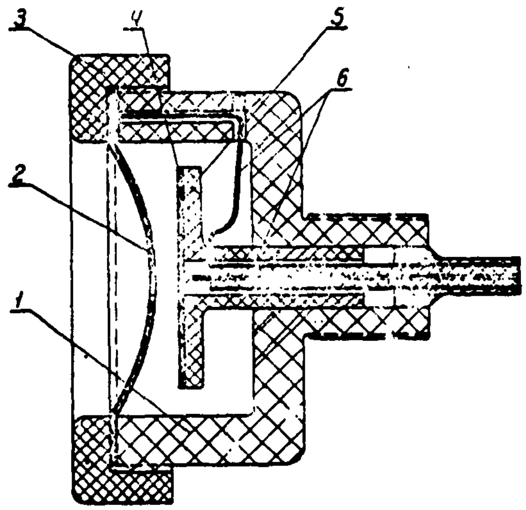

Fig. 2. Schematic diagram of a device for registering the movement of the sheet blank, based on the variation of capacitance

1 - die; 2 - blank; 3 - holding ring; 4 - capacitor plate; 5 - plastic ring for setting initial gap between the capacitor plate and the blank; 6 - wires.